FRAME AND METHOD FOR FABRICATING THE SAME

BACKGROUND OF THE INVENTION

(a) Field of the Invention

This invention relates to frames and methods for fabricating the same.

(b) Description of the Related Art

For structures required to have both light weight and rigidity, such as airplane bodies and wings, so-called monocoque construction or semi-monocoque construction are traditionally employed (see, for example, Japanese Unexamined Patent Publication No. 5-286496). Monocoque construction is formed of a plurality of ring-like frames and an outer panel that covers these frames so that the outer panel, having a small rigidity in itself, is reinforced by the frames, thereby implementing a light-weight and rigid structure. In semi-monocoque construction, as shown in Figure **8**, an outer panel **101** is provided with not only frames **102** but also stringers **103** that extend in the longitudinal direction of the body and intersect with the frames **102**. Semi-monocoque construction thus implements a more rigid structure by both the frames **102** and the stringers **103**.

As shown in Figures **9A** and **9B**, the conventional frame **102** is formed of an outer chord **105** of T-shaped section, a web **106** like a flat plate, and an inner chord **107** of L-shaped section, which are joined together by a large number of fasteners **108**. The conventional frame **102** is fabricated in the following manner.

First, as shown in steps **S101**, **S201** and **S301** in Figure **10**, an outer chord **105**, a web **106** and an inner chord **107** are fabricated in separate steps, subjected individually to surface treatment (see steps **S102**, **S202** and **S302**), and subjected individually to finish coating (see steps **S103**, **S203** and **S303**). Then, these members are assembled (see step **S104**). In assembly, an extension of the outer chord **105** and the web **106** are overlapped, and then fastened along their rims by a large number of fasteners **108**. Similarly, the web **106** and the inner chord **107** are also overlapped and fastened along their rims by a large

number of fasteners **108**. The conventional frame **102** is fabricated in this manner.

As described above, the conventional frame **102** requires many fasteners **108** for the joining between the outer chord **105** and the web **106** and for the joining between the web **106** and the inner chord **107**. Therefore, the weight of the frame **102** is increased by those of the fasteners **108**. Furthermore, the joinings using the fasteners **108** involve the provision of the overlapping portions of the outer chord **105**, the web **106** and the inner chord **107**. Therefore, the weight of the frame **102** is also increased by those of the overlapping portions.

Furthermore, the surface treatment process (see steps **S102**, **S202** and **S302**) and the finish coating process (see steps **S103**, **S203** and **S303**) are necessary for each of the outer chord **105**, the web **106** and the inner chord **107**. This increases the number of process steps, leading to much expense in time and cost. Furthermore, the surface treatment and finish coating processes necessary as a preliminary stage for the assembly process must be carried out for each of the outer chord **105**, the web **106** and the inner chord **107**. This invites an elongated lead time.

SUMMARY OF THE INVENTION

The present invention has been made in view of the foregoing points, and therefore its object is to provide a frame light in weight and small in the number of process steps and a method for fabricating the same.

In a first aspect of the invention, a frame comprises: an outer frame member of T-shaped section having an extension extending inwardly; and an inner frame member having a flat portion abutting against the extension of the outer frame member, wherein the outer frame member and the inner frame member are friction stir welded together with the edge of the extension of the outer frame member abutted against the edge of the flat portion of the inner frame member.

In a second aspect of the invention, the frame according to the first aspect is

characterized in that the inner frame member is formed of two or more frame members friction stir welded together with one abutted against another.

In a third aspect of the invention, a method for fabricating a frame comprises the steps of: preparing an outer frame member of T-shaped section having an extension extending inwardly; preparing an inner frame member having a flat portion abutting against the extension of the outer frame member; and friction stir welding the outer frame member and the inner frame member with the edge of the extension of the outer frame member abutted against the edge of the flat portion of the inner frame member.

In a fourth aspect of the invention, the method according to the third aspect is characterized in that the step of preparing an inner frame member comprises the step of friction stir welding two or more frame members with one abutted against another.

In a fifth aspect of the invention, the method according to the third or fourth aspect is characterized by further comprising, after friction stir welding the outer frame member and the inner frame member, the step of subjecting the outer and inner frame members together to surface treatment or finish coating.

According to the first and third aspects of the invention, the inner and outer frame members are joined together by friction stir welding, and therefore no fasteners are needed for the joining. As a result, the frame can be reduced in weight by the weight corresponding to fasteners that would conventionally be required. Furthermore, since the inner and outer frame members are joined together with one abutted against the other, no overlapping portion between both the members is needed. Therefore, the frame of the invention can have a smaller weight than the conventional frame by the weight corresponding to the overlapping portions.

According to the second and fourth aspects of the invention, the inner frame member is formed by butting two or more frame members together. Therefore, the frame diametral dimension (or lateral width) can be increased. Since the frame members constituting the inner frame member are friction stir welded together with one abutted

against another, there is no need for fasteners for the joining of them and also no need for their overlapping portions. Therefore, the inner frame member can be reduced in weight.

According to the fifth aspect of the invention, the inner and outer frame members need not be subjected individually to surface treatment or finish coating. Therefore, the number of process steps and the lead time can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure **1** is a perspective view of a frame.

Figure **2** is a flow chart of a method for fabricating a frame.

Figure **3A** is a perspective view showing an extrusion for an outer chord.

Figure **3B** is a perspective view showing an outer chord.

Figure **4A** is a perspective view showing an extrusion for an inner chord.

Figure **4B** is a perspective view showing an inner chord.

Figure **5** is a perspective view of another frame.

Figure **6** is a perspective view of still another frame.

Figure **7** is a flow chart of another method for fabricating a frame.

Figure **8** is a perspective view of a body.

Figure **9A** is a perspective view of a conventional frame.

Figure **9B** is a cross-sectional view of the conventional frame.

Figure **10** is a flow chart showing a method for fabricating a conventional frame.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, description will be made of embodiments of the present invention with reference to the drawings.

A frame **1** according to this embodiment is used as a frame in an airplane body of monocoque or semi-monocoque construction. The entire structure of the monocoque or semi-monocoque body is well known, and therefore explanation thereof is not given herein

(see Figure 8).

Figure 1 shows the structure of the frame 1. The frame 1 is formed of an outer chord 2 of T-shaped section having an extension 4 extending inwardly, and an inner chord 3 of L-shaped section having a flat portion 5. In this embodiment, the outer chord 2 and the inner chord 3 are made from aluminum. The outer chord 2 and the inner chord 3 are formed to have an elongate shape, and are curved along the inner periphery of the airplane body. In this embodiment, the inner edge of the outer chord 2 and the outer edge of the inner chord 3 have the same curvature. The outer chord 2 and the inner chord 3 are friction stir welded together with the edge of the extension 4 abutted against the edge of the flat portion 5. The extension 4 and the flat portion 5 are welded continuously on their seam, whereby the frame 1 are formed with a joint 6 extending along its curvature.

In the case of a semi-monocoque body, the frames intersect with stringers and an outer panel is provided on the body surface sides of these members. The frame and the stringer are equal in that they act as reinforcing members. Both the members, however, are different in that the stringer is a member extending along the longitudinal direction of the body, while the frame is a member orthogonal to the longitudinal direction of the body and extending along the inner periphery of the body. By reason of this difference, the frame is actually designed and fabricated from a different view point from the fabrication of the stringer.

Next, a fabrication method for the frame 1 will be described with reference to the flow chart of Figure 2. First, in step S1, a straight extrusion 10 (see Figure 3A) of T-shaped section is fabricated by extruding or drawing. Then, in step S2, the extrusion 10 is bent by stretch forming. In this manner, an outer chord 2 (see Figure 3B) is prepared from the extrusion 10. Thereafter, heat treatment is conducted on the prepared outer chord 2 as necessary to complete the outer chord 2 (see step S3). It is needless to say that instead of fabricating an extrusion 10, a standard extrusion can be purchased and an outer chord 2 can be prepared from the purchased extrusion.

For the preparation of an inner chord **3**, a straight extrusion **11** (see Figure **4A**) of L-shaped section is first fabricated by extruding or drawing in step **S4**. Then, in step **S5**, the extrusion **11** is bent by stretch forming. In this manner, an inner chord **3** (see Figure **4B**) is prepared from the extrusion **11**. Thereafter, heat treatment is conducted on the prepared inner chord **3** as necessary to complete the inner chord **3** (see step **S6**). Also for the inner chord **3**, it is needless to say that instead of fabricating an extrusion **11**, a standard extrusion can be purchased and an inner chord **3** can be prepared from the purchased extrusion.

The fabrication process for an outer chord **2** in steps **S1** to **S3** and the fabrication process for an inner chord **3** in steps **S4** to **S6** are individually conducted. Therefore, both the fabrication processes may be carried out concurrently or one after the other.

Next, in step **S7**, the completed outer chord **2** and inner chord **3** are friction stir welded together with the extension **4** of the outer chord **4** abutted against the flat portion **5** of the inner chord **3**. In this embodiment, the outer chord **2** and the inner chord **3** are welded continuously to draw a curve on their seam. However, there is no particular limit to welding points of the friction stir welding. For example, both the chords may be welded at discrete points on the seam, or may be welded discontinuously to draw a dotted curve.

After the outer and inner chords **2** and **3** are joined together, the process proceeds with step **S8** in which the outer and inner chords **2** and **3** are together subjected to surface treatment. In this case, anodizing is conducted as surface treatment to form a coating on the surface of the frame **1**. Thereafter, the outer and inner chords **2** and **3** are together subjected to finish coating in step **S9**, thereby completing the frame **1** (step **S10**).

For the purpose of weight reduction of the frame **1**, as shown in Figure **5**, the flange **9** may be formed with cutaways (flange trims) **7** or holes (not shown). Alternatively or additionally, the flat portion (web) **5** may be formed with holes **8**. In these cases, the formation of cutaways or holes is carried out after the friction stir welding

in step S7.

As can be seen from the discussion above, the frame 1 according to this embodiment can be reduced in weight because of the absence of fasteners. Furthermore, the outer and inner chords 2 and 3 are joined with one abutted against the other, and therefore they need not be overlapped with each other. As a result, the frame 1 of this embodiment can have a smaller weight than the conventional frame by the weight corresponding to the overlapping portions.

The joining of the outer and inner chords 2 and 3 is made by friction stir welding. Therefore, both the members 2 and 3 can be joined with increased ease and reliability as compared with the joining using fasteners.

Each of surface treatment and finish coating can be conducted on the outer and inner chords 2 and 3 at one time after the joining of them, and need not be conducted on each of them. Therefore, the number of process steps for the outer and inner chords 2 and 3 can be extensively reduced. This results in shortened lead time.

Next, as a modification, description will be made of a frame 15 formed of an outer chord 2, an inner chord 3 and a web 12 like a flat plate with reference to Figure 6. This frame 15 includes the web 12 between the outer chord 2 and the inner chord 3, so that the frame diametral dimension (or the flame lateral width) is increased. The outer chord 2, the inner chord 3 and the web 12 are all made of aluminum. In this modification, the outer chord 2 constitutes an outer frame member, while the inner chord 3 and the web 12 constitute an inner frame member.

Figure 7 shows a flow chart of a method for fabricating a frame 15. In this method, the outer and inner chords 2 and 3 are fabricated in the same manner as described above (see steps S1 to S3 and S4 to S6). On the other hand, as shown in steps S11 and S12, the web 12 is formed by cutting a flat plate (sheet metal) of aluminum into a predetermined shape. Thereafter, the outer chord 2 and the web 12 are friction stir welded together with the extension 4 of the outer chord 2 abutted against one edge of the

web **12**, and the web **12** and the inner chord **3** are also friction stir welded together with the other edge of the web **12** abutted against one edge of the inner chord **3** (step **S7**). Then, the welded outer chord **2**, web **12** and inner chord **3** are together subjected to surface treatment (step **S8**) and then finish coating (step **S9**), thereby implementing a frame **15**.

Therefore, the foregoing various effects can also be achieved according to the frame **15** and its fabrication method.

The number of webs **12** provided is not restricted to one. If necessary, two or more webs can be abutted and friction stir welded together to further increase the frame diametral dimension.

The material for the frames **1** and **15** is not restrictive, and metals other than aluminum can be used for the frames **1** and **15**.

The frames **1** and **15** are not used only for airplane bodies, but may be used for the other parts (for example, wings). Furthermore, the applications of the frame according to the present invention include not only airplanes but also ships, vessels, vehicles and other structures such as buildings.

The frames **1** and **15** are not restrictive in their shape, but can take various shapes. For example, the frames **1** and **15** may have a bent shape or a linear shape.